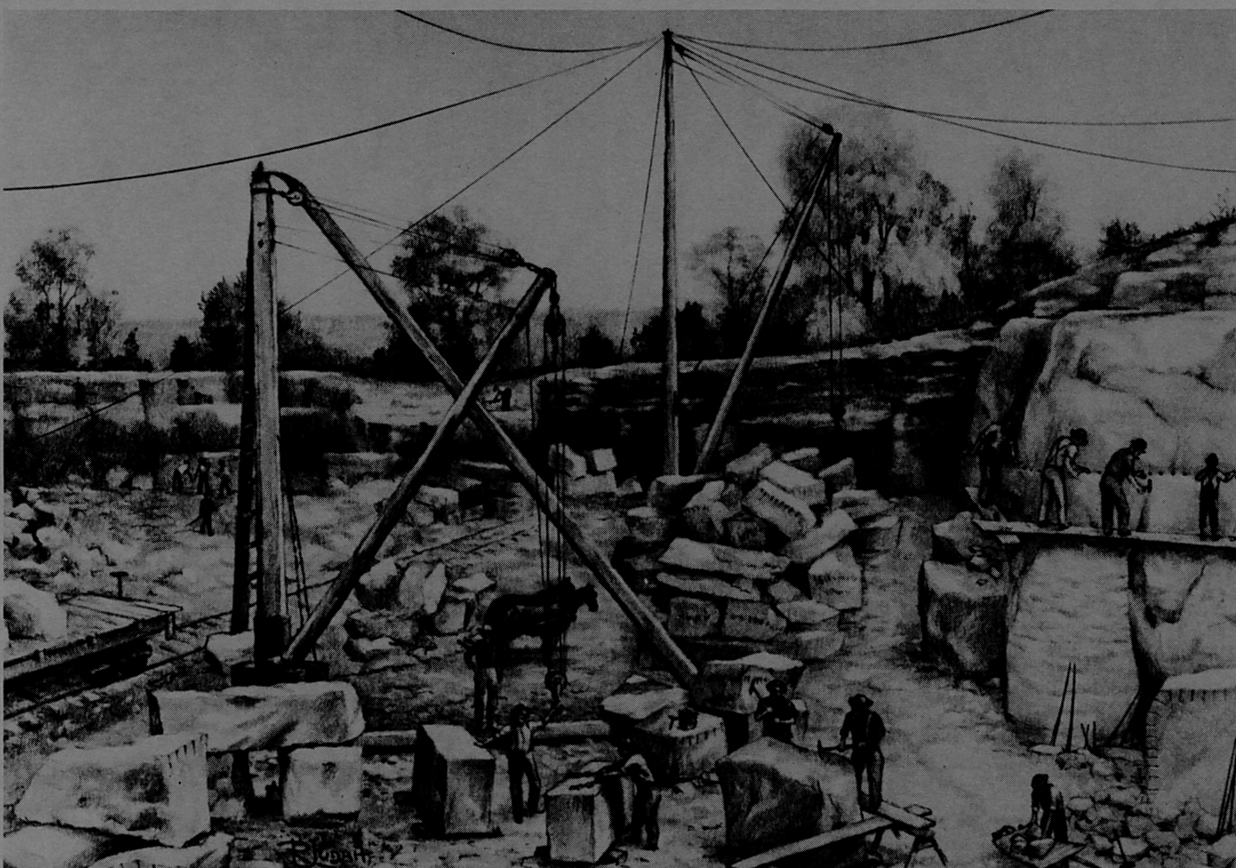
The Salem Limestone in the Indiana Building-Stone District

By JOHN B. PATTON *and* DONALD D. CARR

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY OCCASIONAL PAPER 38



SCIENTIFIC AND TECHNICAL STAFF OF THE GEOLOGICAL SURVEY

COVER ILLUSTRATION: A rendering by artist Robert E. Judah, adapted from early (circa 1865) photographs, depicts the primitive stage of building-limestone quarrying in Indiana.

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Introduction

The limestone building material that has dominated the national market for more than a century is produced in the Bloomington-Bedford district of southern Indiana (fig. 1). Through the years the economy of this two-county area has grown and diversified, so that the stone industry no longer holds the prominent position it once held, but its influence on the economy of earlier years and on the established traditions is inescapable. More than 100 buildings on the Bloomington campus of Indiana University are of limestone from the district, as are nearly all government buildings and countless homes and commercial structures in both Bloomington and Bedford. Oolitic, a small town near the center of the building-stone district, traces its name back to the settlement of the area by immigrant stone workers from England who noticed the similarity of the Salem Limestone to the Portland Oolite, a popular building stone in England. The names of buildings, fraternal organizations, and school mascots testify to the influence of the stone industry on the people. The area has had a rich history because of uncommon properties of a common rock, limestone.

The building-stone district has attracted geologists, architects, and laymen from all states and many foreign countries, and through the years we have guided hundreds of people through the quarries and mills. Always we have been warmly received by the owners and the workers. Partly on the basis of these tours and on questions that were asked during the tours, we prepared a guidebook that was first used at the meeting of the North-Central Section of the Geological Society of America in Bloomington on April 12, 1980. This paper has been modified from that coverage (Patton and Carr, 1980).

History

The qualities that were to make Salem limestone a premium building material of national and international renown were recognized early, and by 1827, only 11 years after Indiana achieved statehood, a building-stone quarry was opened southeast of Stinesville in northern Monroe County by Richard Gilbert (Hopkins and Siebenthal, 1897, p. 357) (fig. 1). In that day of poor roads and no railroads, the impact of the material was largely local, but with the coming of railroads in the 1850’s it was possible for the stone to move to metropolitan markets in all directions, and by the 1870's a substantial volume was reaching a market that included much of the eastern United States. (See Batchelor, 1944, for additional detail concerning the history of the industry.)

The reasons for the rapid acceptance were to be found in the appearance and workability of this stone and in the circumstances of its occurrence. The part of the Salem that came to be developed as dimension stone is a freestone-one that has virtually the same workability in all directions and shows little preferential direction of splitting. The material is fine grained, moderately porous, and, for stone, relatively soft, which permits it to be sawed, planed, turned (fig. 2), fluted (fig. 3), and otherwise worked much as if it were wood. Considerable thicknesses-some tens of feet in many places-although notably cross-bedded, were deposited without impure partings to limit the depths of ledges, and blocks of nearly any size or proportion desired could be removed readily from the quarry (fig. 4).

Such massive stone, desirable as it is for milling, was a problem to those who quarried and shaped stone by primitive methods in the

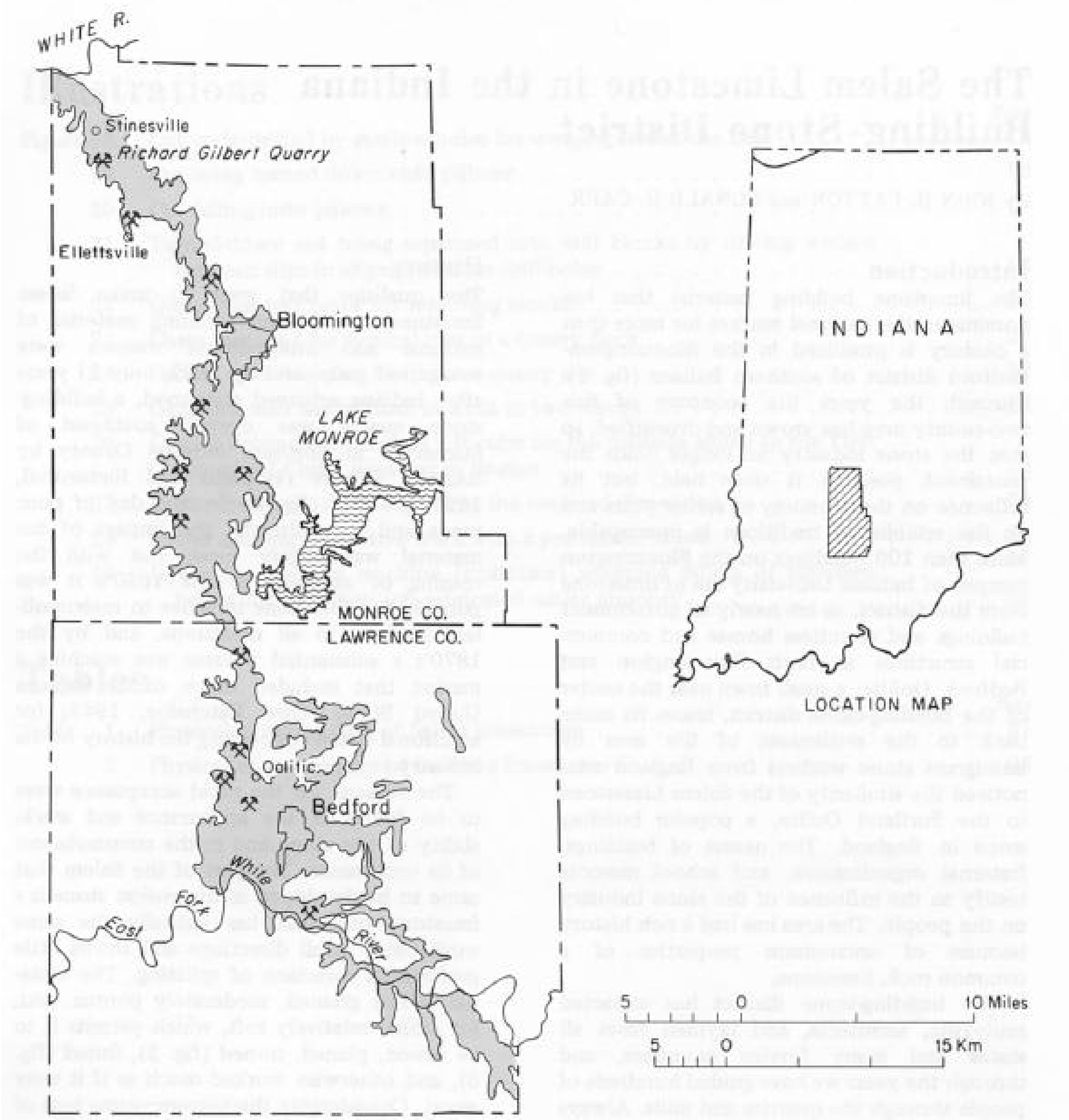


Figure 1. Map of Lawrence and Monroe Counties showing area of outcrop of the Salem Limestone, locations of active quarries in September 1981, and location of the Richard Gilbert Quarry.

days before machinery and power were available. Under those circumstances, the stone that could be taken up and used in its natural bedding thickness (for which Nature had established one of the dimensions) was the more likely stone to be developed commercially, and much stone of this type was produced at various places in Indiana

Figure 2. Turning a baluster on a lathe.

Figure 3. Fluting column that has been turned on a lathe.

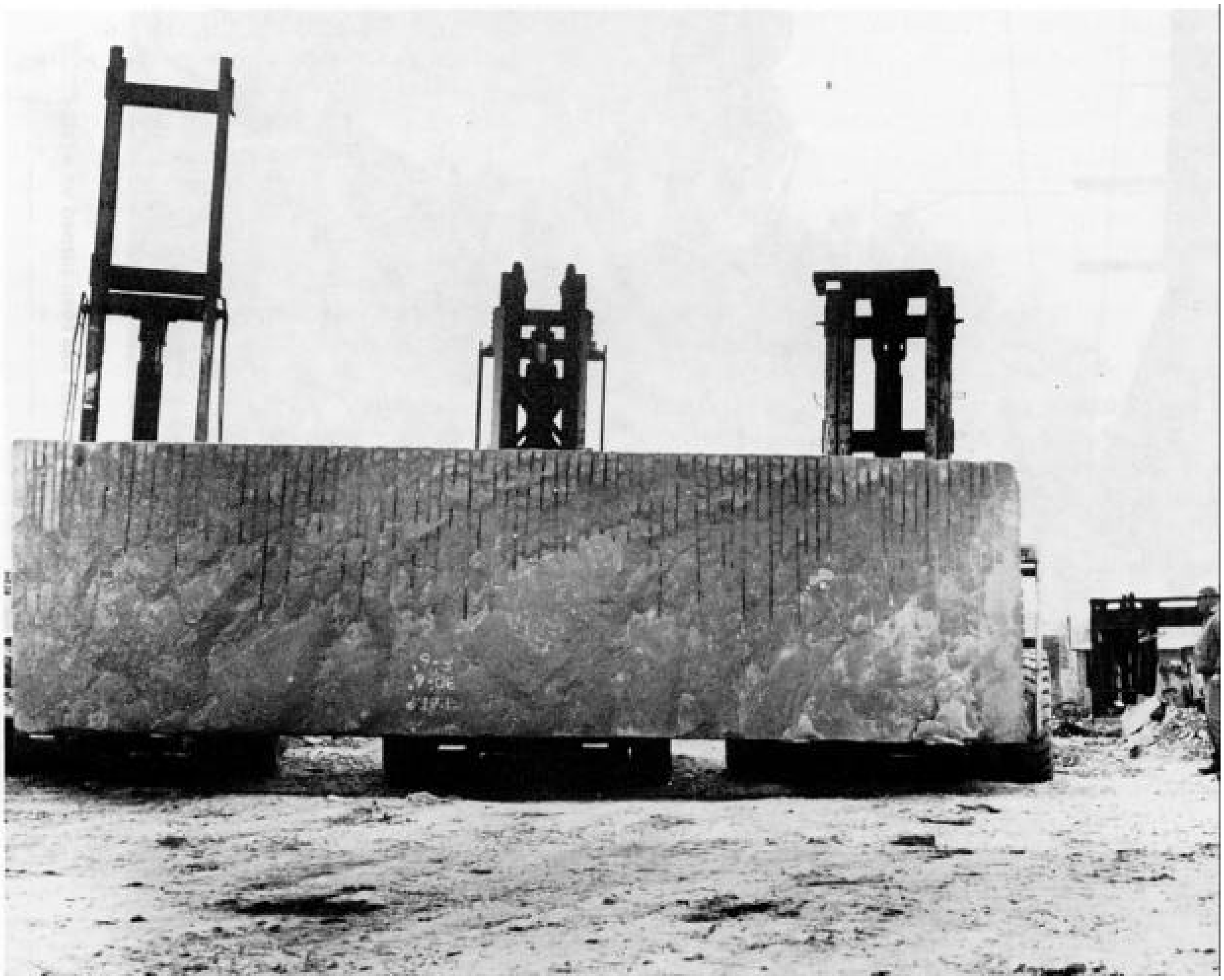


Figure 4. Thirty -ft block for oversize panels. This is one of many blocks, 30½ by 8½ by 3½ ft in dimension, quarried to fabricate single panels 28¾ ft high by 7¾ ft wide by 6 in. thick for a building in Toronto.

during the 19th century-the Laurel Limestone of Silurian age being the most notable example because of its extensive development in several southeastern counties of the state (Foerste, 1898; Rooney, 1970a, p. 4-5). But other Silurian limestones in the Wabash Valley region of northeastern Indiana, as well as Devonian limestone in Jennings County and the Ste. Genevieve Limestone (Mississippian) at various localities, were also quarried and used. With the development of quarrying methods for large blocks and of gang saws to slice the massive blocks to the desired thicknesses for further fabrication, the stone from the Salem quickly overtook and then surpassed in volume of sales all other limestones quarried for dimension purposes in the state, and indeed in the nation.

Within Indiana, the outcrop belt of the Salem Limestone extends from the bluffs of the Ohio Valley in southern Harrison County northward and somewhat westward through western Floyd County, through Washington, Lawrence, Monroe, Owen, and Putnam Counties, and into southwestern Montgomery County, with possibly a few outliers in Parke and Fountain Counties. But for various reasons the principal area of dimension-stone production has been between the White River and the East Fork White River in Monroe and

Lawrence Counties (fig. 1). In part this localization may be attributed to the nature of the sedimentation. Not all rock within the Salem Limestone is of building-stone character and quality, and in some parts of the outcrop belt the ratio of usable to nonusable stone is not sufficiently high enough for the stone to be used. Equally undesirable are strata of suitable stone that are interspersed with unsuitable material. Northward from the White River, increasing thicknesses of glacial drift overlie the bedrock and make exploration difficult and stripping overly costly. Toward the north end of the outcrop belt, little of the Salem is of building-stone quality, and much or all of the limestone may be missing because the post- Mississippian unconformity extends down into, and even through, the Salem Limestone.

The stone was once quarried as far south as the Corydon area, and a substantial amount of building stone was produced in Washington County, whence comes its stratigraphic name, Salem, which is the name of the county seat. Numerous sites were quarried in Lawrence County south of the East Fork White River, but the flood of 1913 eliminated, for a time, the railroad bridges that brought the blocks to the milling district, and the area never revived as a source of dimension stone. Northwestern Monroe County and an adjacent area in Owen County, extending barely across the White River, had active quarrying into the 1950’s, but during the past two decades the northward limit of the productive district has shrunk back to Ellettsville (fig. 1).

Mechanized quarrying and milling, making increasing use of steam for power, brought the industry to a substantial production capacity by the 1870's. Growth thereafter was fairly continuous except for brief periods of economic recession until sales peaked at nearly 10.5 million cu ft' in 1912, after which production ranged from about 8 to 9 million cu ft until a drastic slump (to 2.7 million cu ft for 1918) was occasioned by United States involvement in World War I (Batchelor, 1944, tables 3, 10, and 26).

A major change took place in the nature of building-stone use, without apparent impact on total production from the Indiana district (in the sense that sales continued their general, although vacillating, rise), when construction practice changed from use of thick, solid bearing walls for tall buildings to application of stone (or other) cladding over steel or reinforced concrete framework. The new trend began in the 1890's under the impetus of the architect Louis Sullivan and others, and few tall bearing-wall structures were built after the early 1900’s.

Post-World War I recovery was slow (to only 6+ million cu ft in 1919 and 1920) and was further hampered by a brief recession in 1921 that dropped production to 3.7 million cu ft. From that point the rebound was notably fast. Production jumped to 9.6 million cu ft in 1922, passed the former peak in 1923 by climbing to 11.7 million, and reached an alltime high above 14 million in 1928 and 1929. The effects of the Great Depression were not felt immediately after the stock-market crash of October 1929, as many major construction projects already scheduled, and even begun, were carried to completion. But with some lag behind the decline in the general economy, stone sales slowed modestly in 1930 and significantly in 1931 and then plummeted to 3.5 million cu ft by 1935. Production rose to nearly 6 million cu ft by 1939, then dropped in 1940 and 1941, as the United States became increasingly involved in producing war materials for Great Britain, and descended deeply through the years when this county was itself at war to a nadir of 700,000 cu ft in 1944.

The building-stone industry made good recovery from the dislocations of the World War II period, when quarrying and fabricating stone reached a low ebb and many of the mills were converted to production of strategic materials. Some capacity was permanently lost by the Indiana stone industry in the sense that not all closed quarries ever reopened and that some mills had fallen into disrepair that discouraged their renovation. But a period of building prosperity followed the low level to which construction not

[1] Except for residential ashlar, which is sold by weight, and some trim, such as sills and thresholds, which is sold by linear foot, building stone is measured and sold by cubic foot. A cubic foot of Salem weighs about 144 lb. A ton of stone contains about 14 cu ft.

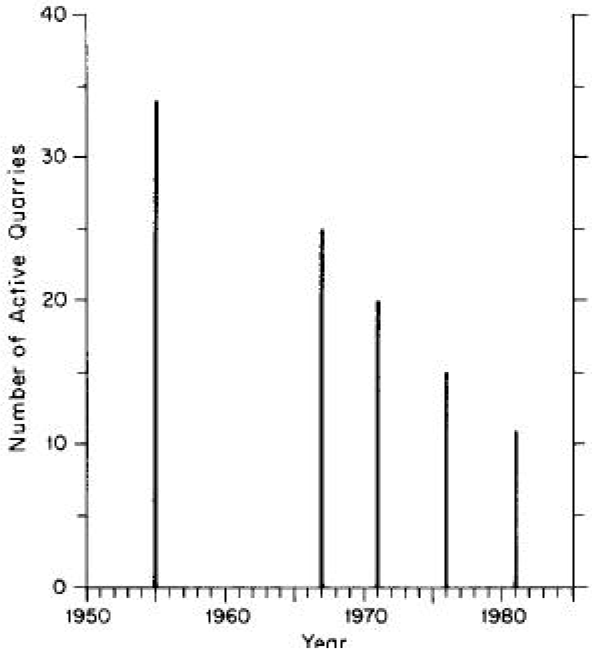


Figure 5. Histogram showing the number of active building-stone quarries producing Salem limestone by year. Data are from directories and maps of the Indiana Geological Survey.

related to the war had fallen, and stone filled a reasonable part of the construction-materials needs to which it was suited into the 1960's. Since the early to middle part of that decade, building stone has lost ground in the building-materials market. Stone sales have been fairly high, at times and in places, but building stone has not had growth commensurate with that of the construction field. Both the number of firms and the number of operating quarries (fig. 5) have declined at even greater rate than production.

From the latter part of the 19th century until World War II, the building-stone industry was the major source of employment in Lawrence and Monroe Counties. Bloomington, with furniture manufacture and Indiana University, was more diversified and less dependent on the fortunes of the stone market than was Bedford. Both were primarily stone towns during the earlier decades of the half century between 1890 and 1940. Past and current quarrying affected the landscape, and the seasonal variation in the level of building-stone activity was a vital part of the economics. Other developments became increasingly important from the 1940's onward, and stone would not now be the dominant factor in the culture and the level of business prosperity even if employment and production were still at the peak levels of the late 1920's. But the building-stone industry has put its stamp on the communities and their life in enduring degree and remains a focus of local interest and pride.

Nomenclature and Stratigraphy

It is peculiar that a stratigraphic unit of such economic significance would have had no proper name of its own during much of the period of its development, but this is the case. Probably the first name applied to the stratigraphic sequence of which the dimension-stone beds are a part was the Mountain Limestone, which resulted from a correlation with British units and which was assigned by David Dale Owen in his pioneering work during the first geological survey of Indiana (1839). Owen used the term for the stratigraphic section extending from the base of the Coal Measures (Pennsylvanian System) down to a sequence of siltstones, sandstones, and shales that fall within the unit now named the Borden Group. Owen made no special mention of the beds that we now call the Salem Limestone, although his reference to oolitic limestone and his prediction that it would be developed for building stone have led to the erroneous assumption that he was speaking of the Salem; the localities that he cited indicate clearly that he was speaking of the truly oolitic beds of the Ste. Genevieve Limestone.

As early as 1858, James Hall used the term "Spergen fossil bed" for a collecting site southeast of Salem in Washington County, and the name, in such variable forms as "Spergen's Hill Bed," "Spurgeon's Hill," "Spurgeon Hill limestone," and "Spurgeon limestone," was used, along with others, intermittently for a century. Richard Owen in 1862 (p. 137) referred to these rocks as "Bedford rock," and the term Bedford was later used by others in several forms, one of which, "Bedford oolitic limestone," was formally proposed by Hopkins and Siebenthal (1897, p. 298).

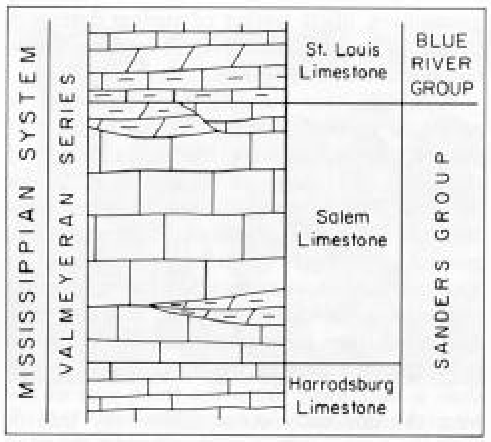


Figure 6. Geologic column showing stratigraphic position of the Salem Limestone.

Besides these names, a plethora of descriptive and trade terms was applied in an apparently formal sense, including Oolitic Limestone, Indiana Oolitic Limestone, and Indiana Limestone. The latter of these has become generic (as a trade term, and not in a stratigraphic sense). Therefore, “Indiana Limestone” to the architectural and building world means the building-stone facies of the Salem Limestone, even though many other limestones have been quarried in Indiana and used for building

The name Salem that was ultimately adopted and that replaced all others was proposed by E. R. Cumings in 1901 (p. 232-233) in a paper sharply critical of the term Bedford, preempted by the Bedford Shale of Ohio. (Additional detail concerning the nomenclature of the Salem Limestone may be obtained from Shaver and others, 1970, p. 152-153.) The Salem, along with a part of the underlying formation and the entirety of two overlying formations, constitutes the Meramecian Series of general usage. The Indiana Geological Survey has dropped the term Meramecian for use in Indiana, and the Salem is within the Valmeyeran Series of Indiana terminology (fig. 6). The Salem rests on the Harrodsburg Limestone (Hopkins and Siebenthal, 1897, p. 296-297), and it is overlain by the St. Louis Limestone as now understood in restricted usage. (Earlier application of the term St. Louis was more inclusive, and the present Salem is part of what was considered to be the St. Louis Group.) In places the uppermost beds of the Harrodsburg Limestone so resemble the Salem that building-stone quarriers have dropped their lowest ledges below the contact, but in general the upper Harrodsburg, even where it resembles the Salem building stone, has coarser texture, is less sorted, and tends to lose the massive character that permits the removal of sound blocks.

The upper limit of the Salem may also be difficult to select. Rocks of distinctive St. Louis lithology rest on Salem limestone of dimension-stone quality in places, but elsewhere a transitional sequence occurs, which either places impure or hard strata within the typical building-stone interval or separates it from unquestionable St. Louis limestone. The correlation problem is of greater significance in subsurface geology, because porous, permeable beds of Salem (in fact, the building-stone lithology) constitute oil reservoirs in the Illinois Basin. Good structural control on the top of the Salem would be valuable in petroleum exploration. Not all workers pick the contact on the basis of the same criteria, however, and formation tops reported in petroleum-trade media incorporate discrepancies (Keller and Becker, 1980).

Conditions of Deposition

The part of the Salem Limestone that is used for building stone was deposited in warm, clear, shallow-marine water--warm enough to sustain an abundant invertebrate fauna; clear enough to have yielded almost no clay or other inorganic sediments; and sufficiently shallow to permit wave action and marine currents to macerate the larger units of shell material, to winnow the organic detritus to remarkably uniform grain sizes, and to distribute calcarenite sand consisting of very small fossils and the well-graded fragments of larger organisms over thousands of square miles of Mississippian sea floor in what is now the American Midwest. Bimodal orientation of crossbedding suggests that these marine sands moved back and forth on a southwestward-dipping paleoslope in response to ebb-and-flood tidal currents, but how far eastward the building-stone lithology extended from the belt of present exposure is unknown. Rock of similar lithology is not present eastward from the Cincinnati Arch, but no evidence is found in three-dimensional study of the building stone to suggest that the present outcrop belt approaches an eastward terminus. A landmass, one that contributed terrigenous debris, must have been tens to hundreds of miles away, because its contribution to the Salem building-stone facies was slight. Discontinuous beds of silty and less calcareous materials were deposited locally, which interrupted the sequence of building-stone deposition in some places and capped it in others. Westward into the subsurface, the building-stone lithology of the Salem extends to the Illinois-Indiana line (Pinsak, 1957, p. 25-26, 34-36, pl. 1) and beyond the center of the Illinois Basin, a distance of 150 to 200 miles from the Indiana outcrop.

Some of the material apparently underwent little distance of transport, as mats consisting largely of delicate fronds of fenestelloid bryozoans are found in places-broken, it is true, to fragments only a few millimeters in long dimension, but still probably too fragile to have withstood any major distance of transport. The greater part of the building-stone bank is heterogeneous in organic compostion, the only common character being particle size, and we must conclude that the greater part of the building stone is composed of winnowed material that was not derived mainly from the invertebrate fauna of the immediate vicinity. A considerable vogue existed in the early part of the century for considering the Salem to contain a so-called “dwarf fauna” (Smith, 1906, p. 1220, 1237-1242), and speculations were advanced to explain environmental conditions that could have caused stunting of various species. The Salem fauna rather than being dwarfed, however, consists of minute species, of infantile forms of larger species, and of fragments from organisms of normal size. Such a situation today, if believed to result from contemporary causes, would be variously attributed to Russian tampering with the ionosphere, illicit testing of nuclear devices in China, or to greenhouse effect from excessive combustion of fossil fuels.

Although the building-stone lithology is generally present from the northern limit of outcrop southward to the Ohio River, it thickens and thins in elongate lenticular strings. The quarries in the Bloomington-Bedford area are distributed as they are, groups of small operations or single or multiple large operations scattered at irregular intervals a few miles apart, because the quarrying firms have found the thicker, more homogeneous part of the lens. In places, less than a mile away from the thick part of the lens, the dimension-stone facies may thin or be interrupted or be replaced by. thin-bedded and impure carbonate units.

Composition

PETROLOGY

The Salem Limestone contains diverse lithologies (Patton, 1953a, p. 65-68; 1953b), but the building stone that is our principal concern in this coverage consists of light-gray to bluish-gray, massive, even-grained, granular, porous, and crossbedded calcarenite. It is generally a pure limestone that consists largely of small fossils and fossil fragments (fig. 7), particularly *Endothyra baileyi* and fragments of fenestelloid bryozoans. The rock has oxidized to light buff to varying depths below the surface, in some places massively and in others along bedding planes or joints, which gives rise to the three principal color categories gray, buff, and variegated (mixed gray and buff).

An impure lithology known in the quarry industry as the “bastard stone” is drab brown, silty, argillaceous, and dolomitic, and it emits a fetid, sulfurous odor from freshly broken surfaces. This facies occurs most commonly above the building-stone facies, but in places it is present as lenses within and beneath the building stone.

Calcite is, of course, the most prominent mineral in the building-stone facies of the Salem Limestone. In most specimens small tests and fragments of shell material are composed of microcrystalline calcite less than .01 mm in average crystal size. Original interstices between the fragments have been

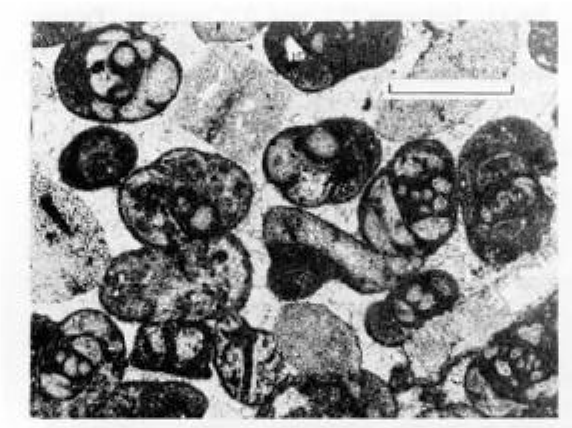


Figure 7. Photomicrograph of a thin section from the Salem building stone. Scale is about 1mm.

largely filled with calcite that generally has crystal size the same as the width of the original pore space. In some specimens the fossil fragments have also recrystallized to the point that each fragment consists of a single crystal of calcite, and all organic structure except exterior shape has been lost.

Dolomite is a prominent constituent of many weathered samples of the building-stone facies. In some specimens only the interstitial cement has been altered to dolomite, but in others the clastic fragments have also been dolomitized, which leaves only the outlines of fossils and fossil fragments as evidence of the bioclastic origin of the rock.

Quartz is present in the building-stone facies both as primary, angular, detrital grains that range from .02 to .06 mm in cross section and as crystals as large as .08 mm, which have formed secondarily in the internal cavities of fossils and in the original pore space between fossil fragments.

Pyrite, hematite, and limonite occur but are uncommon in the building-stone facies. Where present, they have been secondarily deposited by ground water. Rarely limonite has selectively replaced the chamber walls of fossils. Finely dispersed limonite gives a buff color to much of the building-stone facies that is or has been above ground-water level sufficiently long to permit thorough oxidation of the extremely small iron content

Chert is found in a few specimens but in places is abundant m thin zones of the building stone. It is generally milky white or blue and occurs as grains or small stringers formed by the selective replacement of fossil fragments or interstitial cement. Chalcedony that contains beekite rings is found replacing shell material, but it is not common. Leucoxene may be found but is rare.

Endothyra baileyi is the most common and most distinctive fossil in the building stone, and abundant specimens that range from 0.6 to 1.0 mm in long diameter in adult specimens serve to identify the Salem Limestone in both outcrop and subsurface samples in Indiana. Some zones within the building-stone facies are largely composed of *Endothyra* (fig. 7).

Fragments of small crinoid stems are the second most abundant identifiable organic remains. Bryozoans, particularly fenestelloids, are also important rock-forming organisms in the Salem. Without exception the bryozoan remains were transported to their present resting place by currents and waves, as whole specimens do not occur. Besides these forms, ostracods and minute gastropods, pelecypods, and brachiopods are present in the building stone. Fragments of larger brachiopods and pelecypods are also common. Spicules and rod-shaped organic fragments are generally present and are abundant in some zones.

Porosity was high in the original, unconsolidated bioclastic deposits. Most of the building stone is still fairly porous, but in some zones and some localities calcite has filled nearly all original pore space between the particles and within the chambers and interior openings of the fossils. Some of the cavities that have not been completely filled are lined with botryoidal layers of calcite.

Crossbedding is present on a microscopic scale in some specimens. The layering is caused by fairly uniform orientation of the particles, the long dimensions being parallel to the surface on which deposition took place. On weathered outcrop, crossbedding is well displayed in many places. Most beds are less than 1 ft thick but some exceed 3 ft. Crossbeds most commonly dip 11° to 15° from the horizontal and have a preferred bimodal orientation between southwest and northeast. Although crossbedding is the dominant sedimentary structure in the building-stone lithology, other structures, such as ripple marks, load casts, and burrows and trails, are not uncommon.

True ooliths are nearly absent from the Salem Limestone. Some zones contain fossils and fossil fragments coated with concentric layers of calcite, but these coatings generally do not constitute more than 20 percent of the radius of the particles.

Clastic particles that compose the building-stone facies of the Salem Limestone are strikingly well sorted. *Endothyra*, ostracods, and minute gastropods were deposited whole, but crinoid stems 0.5 to 1.0 mm in diameter were separated to their constituent rings or to pairs of such rings. Stems of larger crinoids were broken to fragments about 1 mm in diameter. Bryozoans, pelecypods, brachiopods, and the larger gastropods were also broken to this size. Many of the fragments are no longer identifiable. This advanced degree of sorting indicates that fossil content was controlled largely by transportation and particle size rather than by the character of the organic life in the immediate area at the time of deposition

The less pure beds of the Salem are also fragmental. Dolomite is much more abundant than in the building stone and generally consists of rhombs .01 to .02 mm across. Quartz is also present in the impure facies and consists of angular grains about .02 mm in diameter. Pyrite is not present in large amount but is fairly common and occurs as secondary grains, generally .02 to .04 mm in diameter, that have developed in former pore space. Both hematite and limonite are more common than in the building stone. In some specimens these iron oxide minerals may be seen spreading from grains of pyrite, and it is assumed that most of them originated in this manner.

GEOCHEMISTRY

Much of the building stone may be classified as high-calcium limestone, as the calcium carbonate content exceeds 95 percent and the other constituents also fall within the acceptable range for many high-calcium purposes, alumina being generally below 0.5 percent, silica between 1 and 3 percent, and Fe_2O_3 between 0.1 and 0.3 percent (Patton, 1953a, p. 68-70). At numerous places, both within the present building-stone quarry district and outside it, the building-stone lithology, and even parts of the underlying Harrodsburg Limestone, offer potential for production of chemical limestone (McGregor, 1963, p. 27-31, 36, 38-39, 41, and 43-44; Rooney, 1970b, p. 10-12). In the late 1800’s and early 1900’s the Salem was used for lime manufacture (Ault and others, 1974, p. 19-29), and in 1980 a company began producing it for glass raw material, driving an underground mine from the face of an abandoned building-stone quarry.

The part of the Salem that is not used for building stone is considerably less pure and appears not to offer promise as material for chemical uses (Patton, 1953a, p. 68-70).

Quarrying

Early-day quarry sites were selected largely on the basis of the distinctive outcrops that natural exposures of the building stone exhibit because of the massive character of the rock. Both outcrops and artificial exposures, such as road cuts and excavations, have continued to interest and guide the industry throughout its history, but test drilling, and particularly coring, came to be more important as exploration methods for new sites and for advance appraisal of extensions to active or depleted quarries. Virtually no practical density of coring can prove the suitability of a site, but cores properly spaced and adequately studied can greatly increase the prospects for success, and certainly cores have prevented the opening of quarries that would have been doomed to failure.

Overburden is of three principal types: (1) unconsolidated material, generally residual soil that tends to be red unctuous clay at depth and that ranges in thickness from zero at the outcrop to as much as 20 ft in pockets and depressions on the surface of the stone; (2) bedrock of lithology not suitable for building stone, either the lower part of the St. Louis Limestone that overlies the Salem or ledges of upper Salem that fall within the impure “bastard stone” category or that, if pure, are too indurated and hard for

Figure 8. Removing soil overburden by dragline and cutting rock overburden by channeling machines.

satisfactory milling; (3) surficial layers of building stone that are too weathered, irregular, or intersected by grikes to yield sound blocks of usable size (fig. 8). The soil was removed in the early days by horse-drawn scrapers and hand labor. Bulldozers and powered scrapers and shovels long ago supplanted the primitive methods, although hand labor is still required for final cleanup of grikes and other irregularities. Hydraulic sluicing was used for a time to remove unconsolidated overburden (fig. 9), but the practice appears to have been discontinued. The rock overburden, if thick, may be loosened by drilling and blasting before removal, but explosives must be used with wariness to prevent damage to the underlying building stone. Black powder in untamped holes was the system used for many years before the development of more sophisticated blasting techniques, and quarry operators still would not attempt to blast the full thickness of rock overburden but leave a protective zone above the stone to be quarried. The lowermost part of the overburden, whether of unsuitable lithology or weathered and irregular building stone, is generally removed by the same methods used for producing mill blocks.

Waste stone so quarried must be placed somewhere, and in the opening of a new quarry it is frequently necessary to stack waste blocks adjacent to the quarry opening,

Figure 9. Soil overburden being removed by hydraulic sluicing.

which may mean that they cover ground later needed for quarry expansion and must be handled a second time. Besides the overburden removed as block, some of the stone quarried from the working ledge must generally be set aside because of irregular shapes that do not justify gang sawing or because of weathering, color, texture, or flaws that cause its rejection. Among the flaws are stylolites, dry seams (as unannealed joints are called), and glass seams, which are fractures resealed by calcite. (Definitions of .these and other terms commonly used in the trade may be found in Patton, 1974.) Many of these rejected blocks are perfectly sound stone but do not meet the requirements for the particular type of stone that is being sought at the time. Therefore the grout piles, some stacked in orderly fashion (fig. 10) and some in tumbled masses of mixed large blocks and unshaped fragments (fig. 11), may contain material that is usable for some present needs but that was considered waste at an earlier time. Grout piles have been reworked, both for salvage and for clearing land for other use, but most of them remain.

Once a quarry opening has been developed to its full intended depth, block overburden, nonblock overburden, and rejected material from adjacent working ledges may be placed in the abandoned opening. Many such former quarry holes are no longer recognizable, as they have been graded over and some of them have been paved or vegetated. Therefore the industry through its normal practices has reclaimed some of the earlier quarry sites.

Reclamation of land disturbed by surface mining, quarrying, and development of pits has become a matter of increasing concern during the past decade. Public Law 95-87, the Surface Mining Control and Reclamation Act of 1977, applies to surface mining of coal, but in its earlier forms it included other mineral commodities, and in final form it mandated a

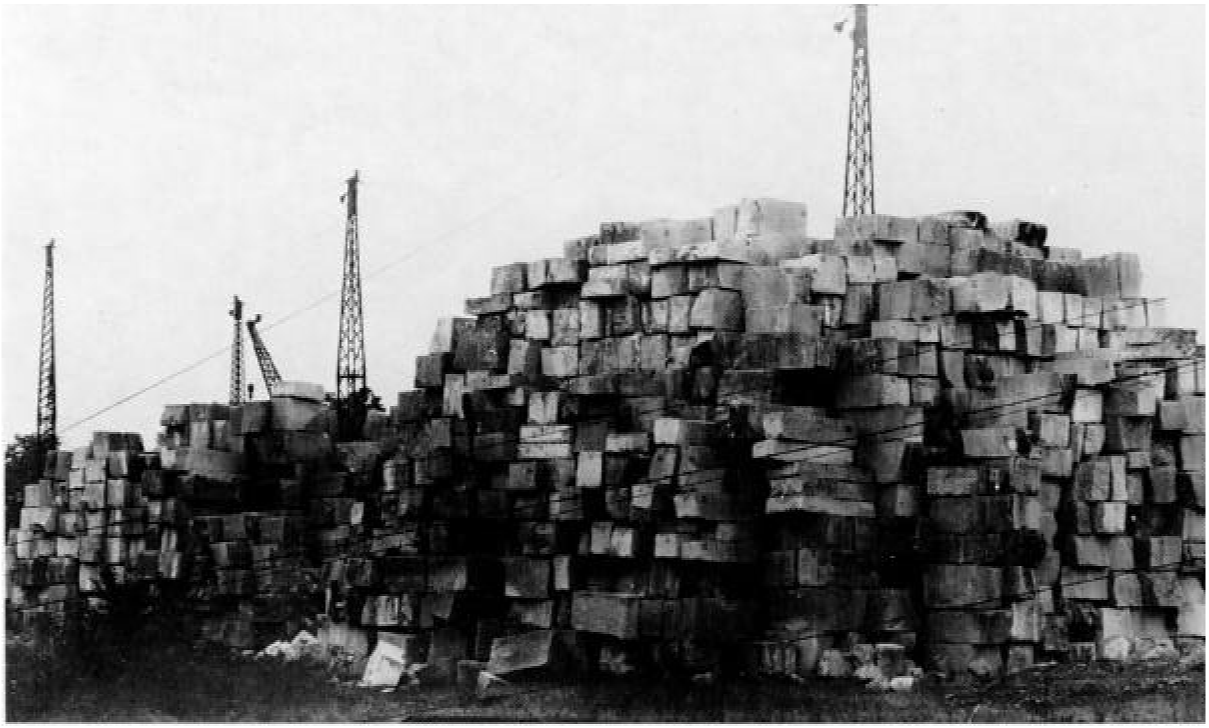


Figure 10. Waste stone (grout) stacked compactly to save space.

Figure 11. Mill blocks (left), stacked waste (center), and randomly piled waste (right).

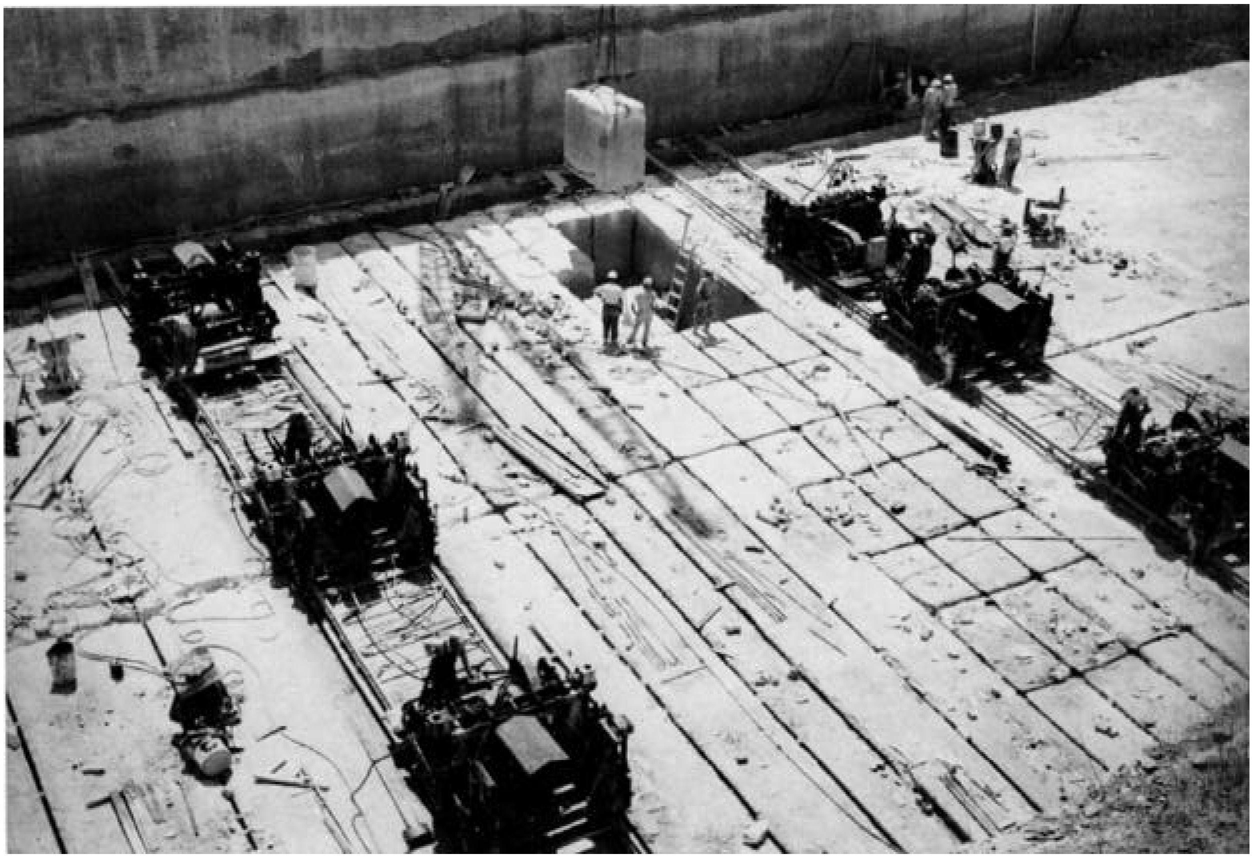


Figure 12. Channelers operating on a new floor. The block is being hoisted from a key slot three blocks wide to provide space to turn down adjacent long cuts.

study of the applicability of the act to surface mining other than that of coal. This study was carried out, as directed by the act, through the National Academy of Sciences-National Research Council, which established a Committee on Surface Mining and Reclamation (COSMAR) that set up nine study panels, one of which was for dimension stone. That panel visited dimension-stone operations in Vermont (marble, granite, and slate) and Indiana (limestone) and prepared a working paper that was not published but that became a part of the record. The COSMAR report (Committee on Surface Mining and Reclamation, 1979) stated (p. xxi), in a section entitled "Summary and Findings":

> A principal fording is that most non-coal mineral mines, despite their obvious diversity, can be considered in two major groups: the numerous, mostly small, units mining construction materials in all of the States; and the few gigantic metal mines and other deposits confined to limited regions. With few exceptions neither of the two groups is amenable to the coal mining practices addressed by the Act (Section 5.4).

The report was transmitted to the Council on Environmental Quality, which in 1981 reported that "the Council does not at this time recommend that the Congress enact any new legislation regulating noncoal minerals mining and reclamation on public or private lands" (American Mining Congress, 1981).

The principal method for separating mill blocks involves the use of channeling machines or of wire saws. Channelers are mobile devices that travel on narrow-gauge tracks (fig. 12), moving slowly back and forth over the prescribed length of the particular cut that they are making. They deepen a channel on one side of the tracks, or two

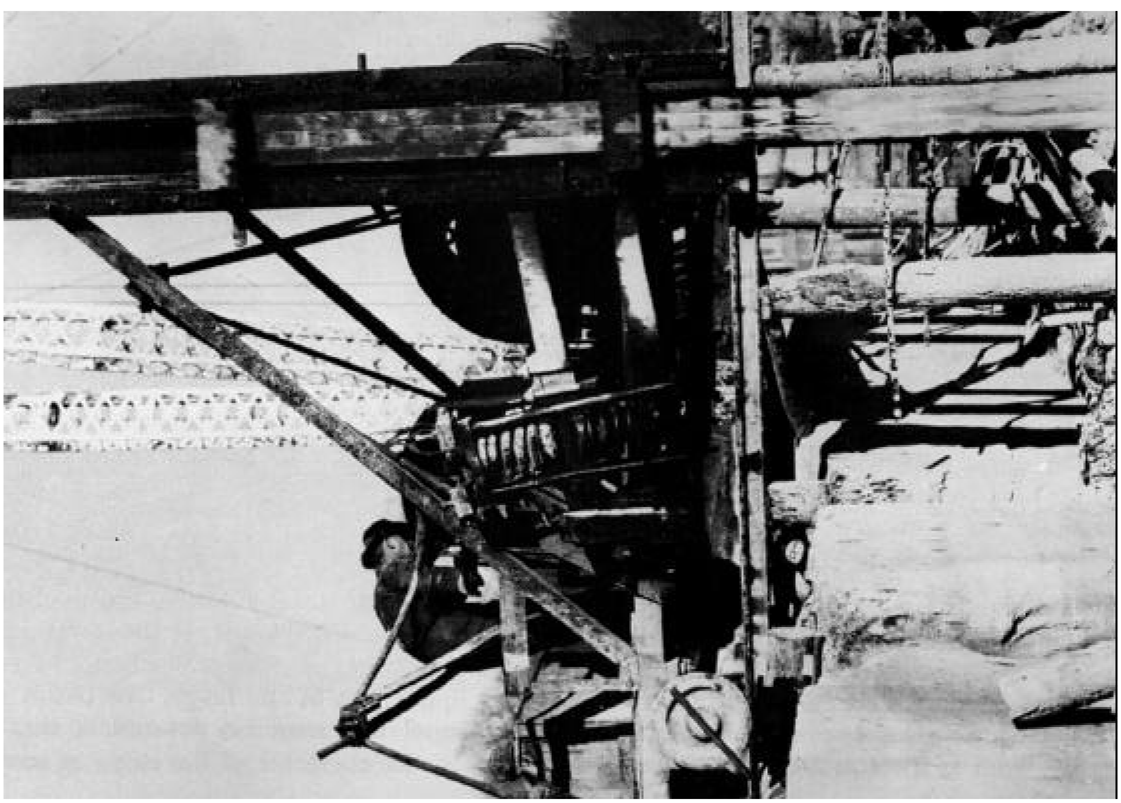


Figure 13. Channeling machine on a trestle. Sheaved rods are driving bits at depth in the channel

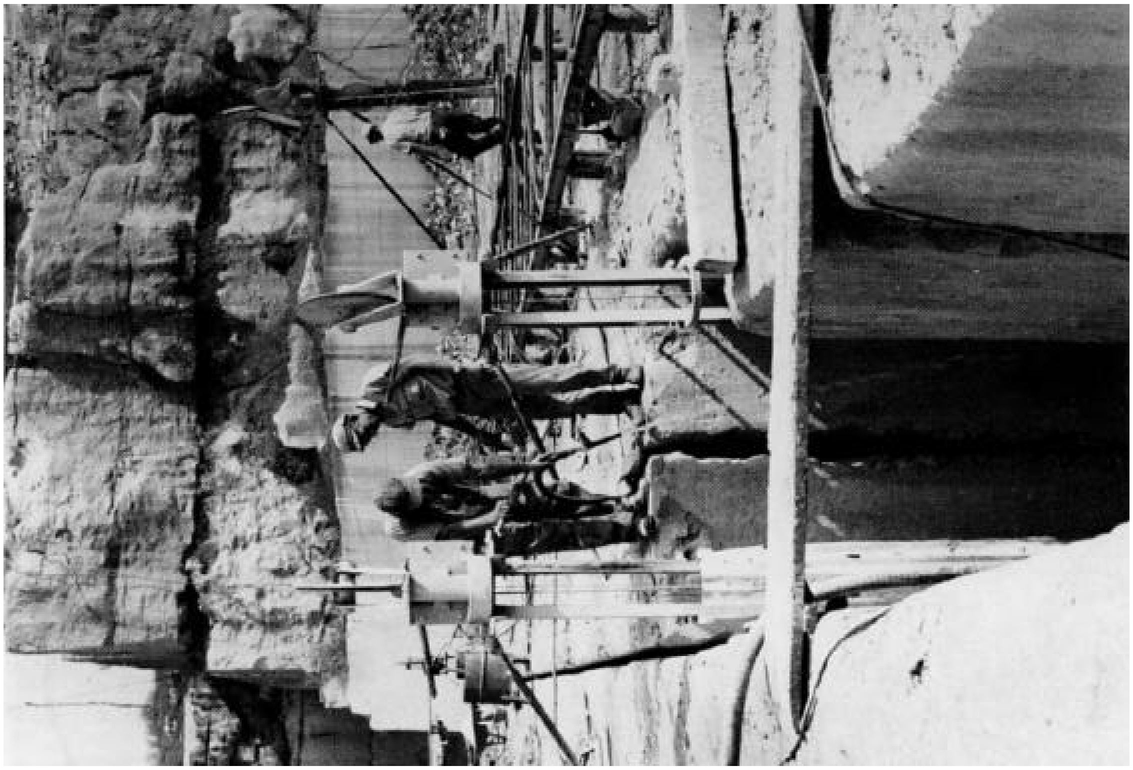


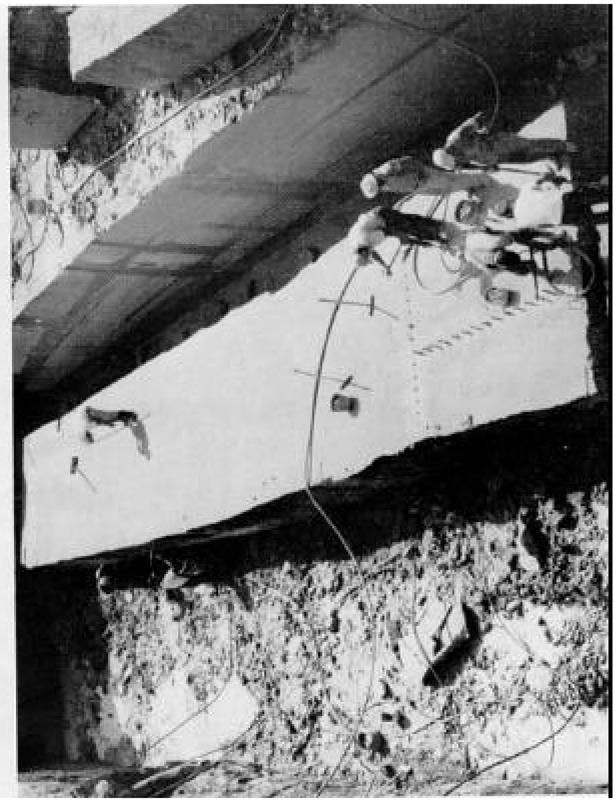
Figure 15. Multiple wire-saw cuts in progress.

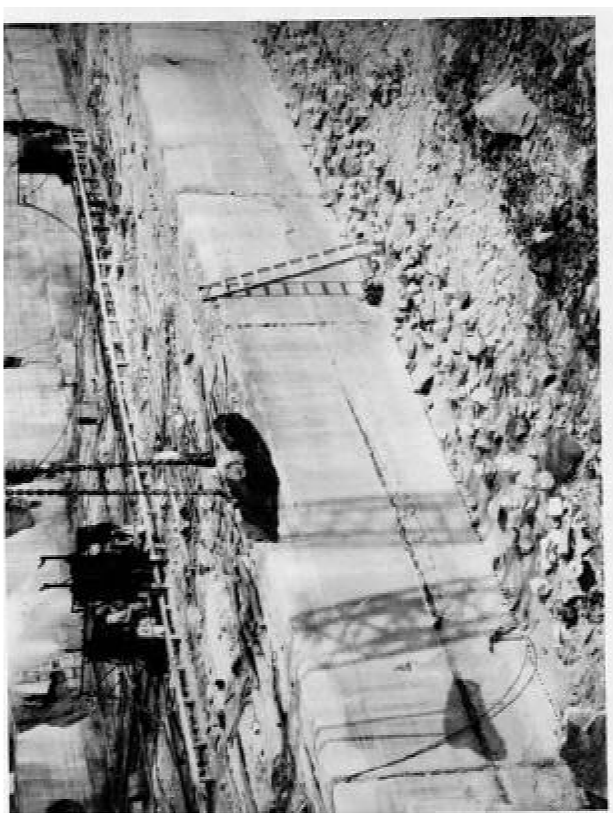
Figure 14. View looking north in a quarry at Oolitic. Most of the working ledge has been channeled, but the machines are still at work. Successively deeper ledges step inward. The left wall shows both soil and rock overburden. The turned cut near the center is being split into mill blocks.

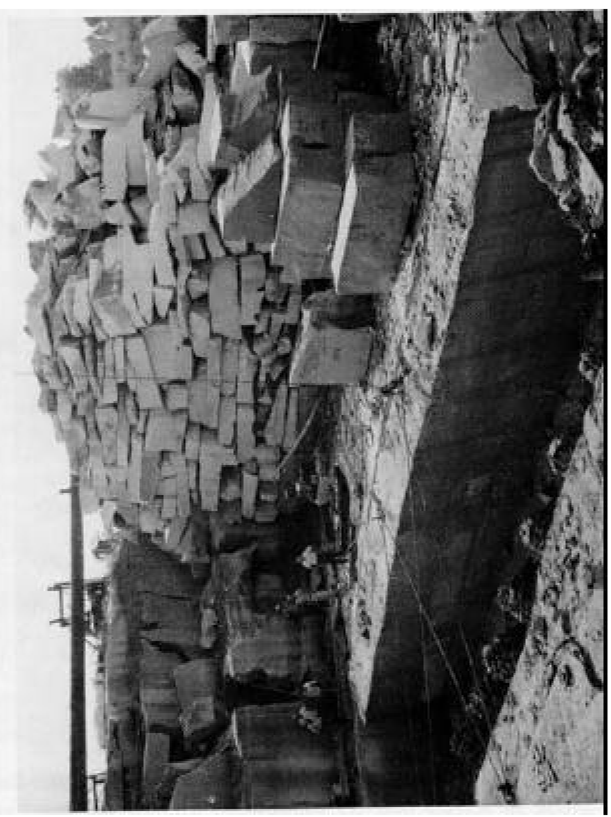
channels straddling the tracks, a fraction of an inch to several inches at each pass through the pounding of a set of bits at the bottom of sheaved rods actuated by a cam or directly by a piston (fig. 13). The depth of the channel cut may range from as little as 5 or 6 ft to as much as 13 ft. In the earlier days of the industry typical depths were in the lower part of this range, and in modern practice they are in the upper part of the range. The depth of the channel cut may be determined by a change in the character of the stone at some

Figure 16. Channeling machine making short crosscuts to free key blocks.

Figure 17. Wire-saw assemblies in the key slot. In the foreground note the offset key slot, cut to block units but not yet freed and removed.







depth that would make it impractical to add another foot or two of a different lithology to the ultimate block. But in other places the lithology remains unchanged from the ledge being channeled to the underlying ledge, and in such places the depth of the channel cut will be the maximum that the equipment can cut effectively. For the most part, the successive ledges in a deep quarry are not bottomed at bedding planes or other necessary limitations, and the ledges are commonly of fairly consistent height. A channel cut cannot be made flush with the quarry walls, and therefore each successive downward ledge steps inward about a foot (fig. 14).

Perpendicular to the parallel channel cuts thus described, there must be other channeler or wire-saw cuts at the lateral extremities of the floor to be quarried, and unless the entire width of the ledge is to be handled in the next step as a single unit, intervening crosscuts are made at intervals of 30 to 60 ft and to the same depths.

Channeling-machine production has been augmented by wire saws, which are more economical to operate. A power-driven endless helical wire is drawn, initially over the surface of the ledge and later in its own slot, carrying a mixture of water and quartz sand as abrasive. The wire is under tension, exerting constant pressure on the bottom of the slot, and feeding over sheaves that slowly descend as the slot deepens. The resulting cut is slightly convex but may be flattened at the end of the run by continued operation under tension. Typically a single length of wire, actuated by a power unit that may be out of sight over the quarry rim, is so rigged over an elaborate assembly of pulleys and posts that it is performing many cuts at different places in the quarry simultaneously (fig. 15).

If one side of the quarry is open, as it may be on a hillslope, undercutting and removal of the stone, once it is free of the ledge except at the base, pose no difficulties; but in the opening of a new quarry on a fairly horizontal surface, or in the deepening of an enclosed quarry, special steps must be taken at the outset. One of the long cuts, as they are called, perhaps 4 ft wide by 10 ft high by 30 or 40 ft long, is crosscut by short runs of a channeler (fig. 16) to some typical mill-block size. One of these blocks, the key block, is wedged loose, generally breaking irregularly and requiring continued dental work to remove the lower parts to the full depth. The adjacent blocks can then be underdrilled with a series of jackhammer holes, spaced a few inches apart, as near the base and as nearly horizontal as possible. Into these, wedges are driven, which forces apart metal half sleeves called slips (to transmit the force back into the stone and prevent it from simply shattering around the hole), and these adjacent blocks are thus split free of the new lower floor and can be hoisted out by the derrick or the crane. When the key slot (fig. 17) is thus cleared through the removal of the successive blocks constituting one cut, the adjacent cut may then be underdrilled (fig. 18), wedged loose at its base, split into blocks of manageable size by the drilling and wedging process, and hoisted free in sections. As soon as the opening created is wide enough to accommodate the full height of the remaining cuts, broken stone less than a cubic foot in size is stacked on the new lower floor in a row of piles called pillows, and the underdrilled and wedged-free cut is turned down (figs. 19 and 20), by using wire rope attached through sheaves to a power source, onto the pillows, which are intended to prevent breakage of the cut as it topples. Once on its side the cut is sectioned into quarry blocks of the size desired, by using wedges and slips in pneumatic-drill holes (fig. 21).

Figures 18-21 *(on facing page).* 18 (upper left when turned to viewing position), Cut underdrilled by shallow holes for wedging free at the base; 19 (lower left), Cut being turned down (note taut lines) onto pillows; 20 (upper right), Cut falling (note slack lines) onto pillows; and 21 (lower right), Turned-down cut being separated into mill blocks by driving wedges between slips in aligned shallow drill holes.

Figure 22. Quarry-bar technique for removing blocks. Little used in the Indiana stone district, it leaves a ribbed vertical texture as a result of the slim parallel drill holes and the removal of the intervening web by the broaching bar.

The blocks are graded and labeled with paint in a system that commonly indicates the quarry, the ledge in the quarry, the year cut, and the classification of the stone in terms of color, texture, grain size, and porosity. Industry grades of stone, generally corresponding to increasing grain size, are select (buff or gray), standard (buff or gray), and rustic (buff or gray) and a classification called variegated, which is an unselected mixture of these three grades with both buff and gray colors (Indiana Limestone Institute, 1977, p. 11).

The graded blocks may be stacked temporarily at the quarry, transported to a stockyard and put into inventory, hauled to a local mill, or shipped to a distant mill.

The practices described are those that have been most extensively used in the district for a long time. They do not differ substantially in their essentials from the method used by 19th-century workers (Hopkins and Siebenthal, 1897, p. 326-336), but many refinements have been effected. Tools are better; special steels more suitable for various aspects of the work have been developed; steam

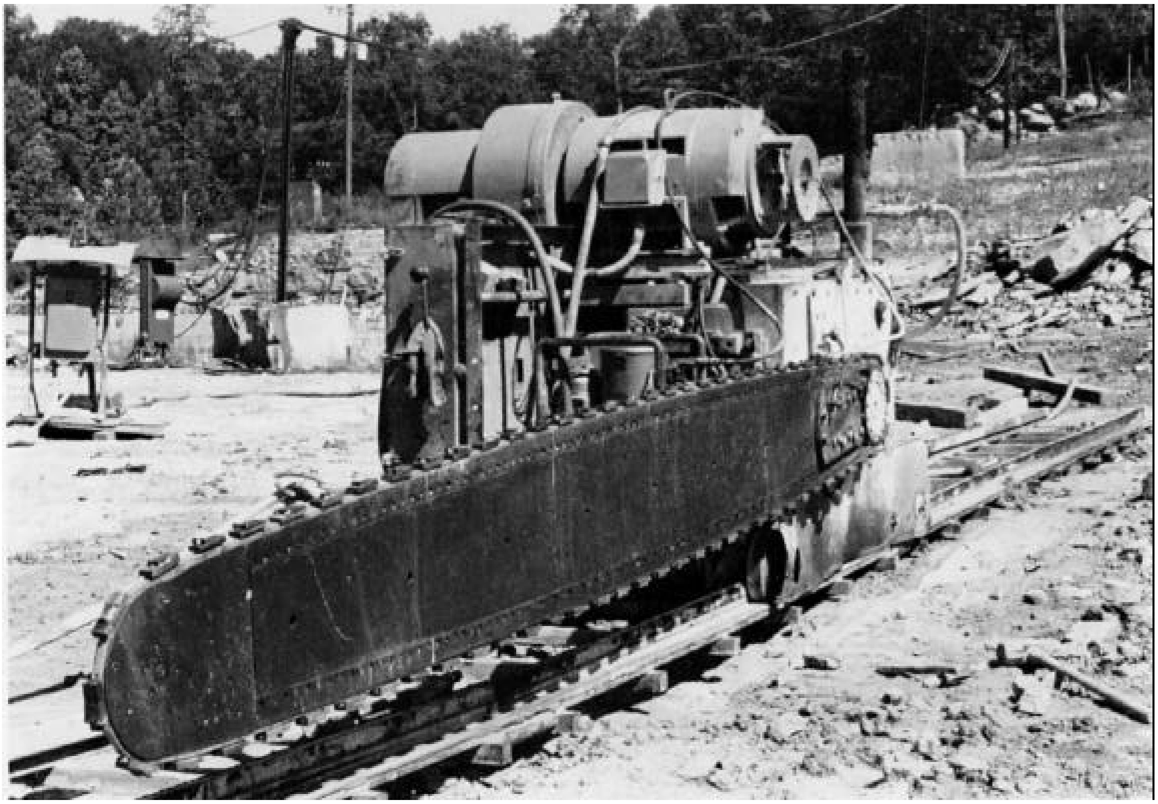


Figure 23. Chain saw used for vertical cuts in a quarry floor..

raised by coal as the source of power has been replaced by electricity, gasoline engines, diesel engines, and compressors; and steam, if used, is raised by petroleum fuels. Virtually every technique developed elsewhere in the country or in the world for removal of quarry blocks has been tested in the Indiana district. Individual quarry operators have been innovative and have experimented with devices and systems of all sorts.

As an alternative to standard channeling or wire sawing, the quarry-bar technique has been used, and successfully, in at least one operation. The process is one in which parallel percussion-drill holes are driven close together in a straight line, controlled by the heavy quarry bar, along which the drill slides and is locked into successive new positions, and then the webbing between the drill holes is removed by a broaching bar, also pneumatically driven (fig. 22).

Chain saws of several types have been tested in the district. A particularly intricate chain saw that can use either tungsten carbide or diamond tooth inserts and that travels on a track is currently in use at one quarry (fig. 23). The same company has made quarry-floor cuts with a gigantic circular saw, also tracked. The district may be the only stone-producing area in which gantry cranes have been adapted to handling blocks at the quarry (fig. 24).

Figure 24. Gantry crane hoisting blocks at a quarry site.

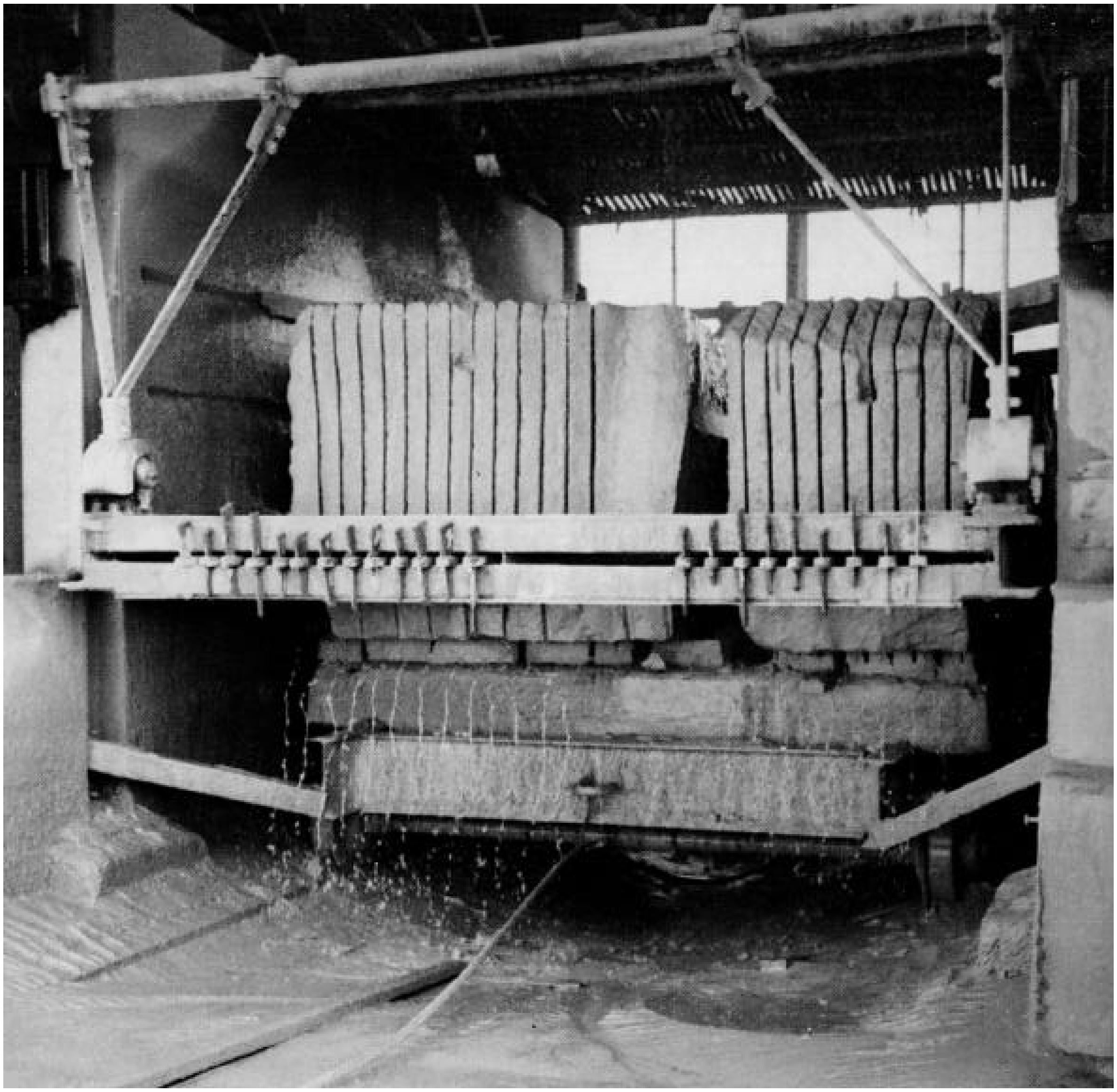
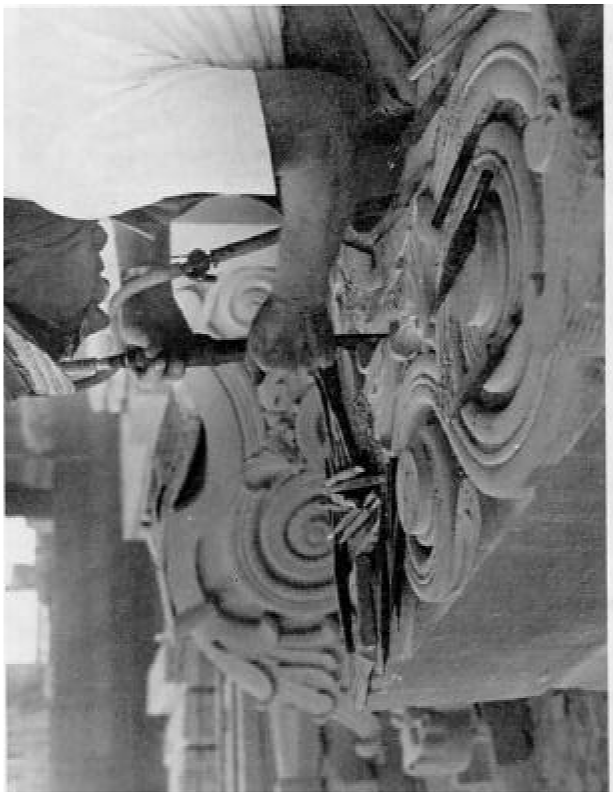
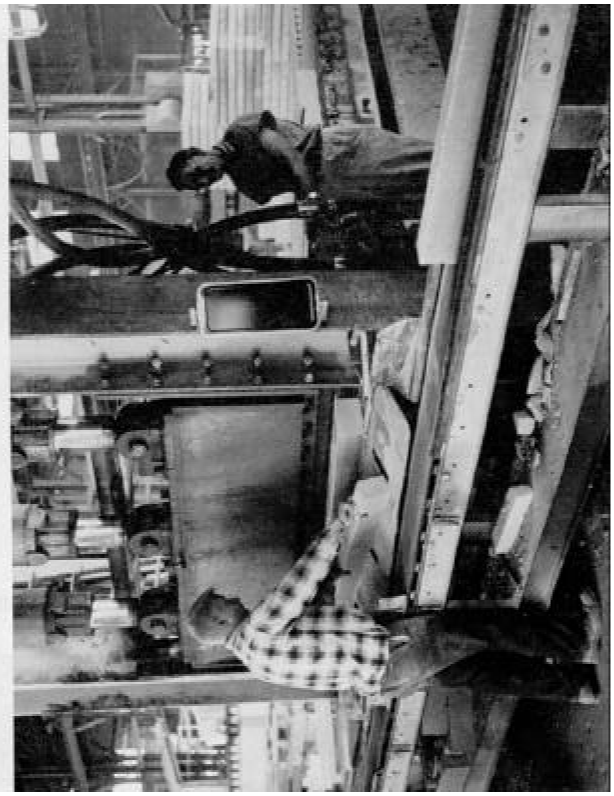


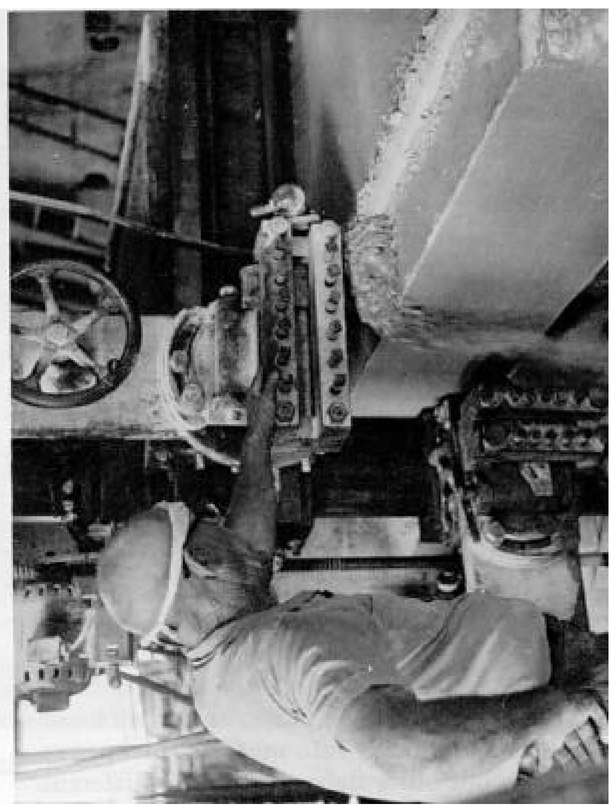
Figure 25. Gang saw near the bottom of a cut in two blocks.

Milling

Except for such unusual masonry units as large columns, capitals, and column bases, most fabrication of the Indiana Limestone begins with gang sawing (fig. 25), in the course of which a quarry block is sliced vertically into 'sheets of whatever thickness is desired for some final purpose. Some blocks are sliced completely into uniform thicknesses of stone, but other slabs are cut into different thicknesses. Even large cubic pieces destined for carving into oversize capitals (fig. 26) or massive statuary may be squared to maximum dimensions in the gang saw or, less commonly, by wire saw. For gang sawing, the quarry block is securely chocked on a wheeled bed and run on rails under the frame. A cradle, actuated by a long beam called the pitman and driven by a cam, carries a battery of parallel steel blades back and forth across the block, which slices it from top to bottom. The cutting action may be obtained by the







abrasion of quartz sand or crushed chert called chat fed into the blade slots by a stream of water, which yields the sand-sawed or various chat-sawed finishes, or steel shot may be introduced to do the cutting and to produce the shot-sawed finish characterized by parallel markings on the stone where the shot has worked between it and the blade. Increasingly common in recent years has been the use of gang-saw blades that have diamond-impregnated tooth inserts and that cut much more rapidly.

The next step for most cut stone, which in the trade means masonry units that go through the mill on their own individual job tickets and that are destined to be set at a particular spot in the finished structure, is to be trimmed by a diamond-toothed circular saw to the approximate final maximum dimensions, after which the units are planed (fig. *27),* routed, and otherwise shaped to the extent possible by machine processes. Some units require handwork of various kinds, including carving, most of which is done by pneumatically driven chisel in the hands of a skilled artisan (figs. 26 and 28).

Another category of fabricated stone consists of standard stock pieces for use as sills, lintels, and thresholds and for other purposes for which they can be cut to length by the mason on the job.

Still another type of finished product that is made and sold in large volume is stone for job-fabricated ashlar construction. Stone for this purpose is modular and comes in course heights nominally called deuces (2¼ n.), fives (5 in.), eights (7¾in.), and tens (10½ in.), so cut that a pair of deuces plus the mortar joint between them equals the height of a five, and a five plus a deuce and the mortar joint equals an eight, and so forth. The heights course out with brick set with half-inch mortar joints.

This material is available in the various sawed finishes mentioned, but it is sold most extensively as split-face veneer, a term deriving its name from the method of preparation. Sheets of stone, cut by the gang saws to modular thicknesses of 2¼ in., 5 in., or so forth, are fed through a hydraulic shear called a guillotine (fig. 29), which snaps off billet after billet for a wall thickness of about 4 in., to be used over backup of some sort-frame and block are most common to produce the slightly rustic effect of rough surface even though the stone has been cut to dimension and the mortar beds lie between smooth, sawed surfaces. Split-face veneer is used extensively for residential and low-rise commercial and institutional construction.

Such ashlar stone may be purchased, supermarket style, from the companies that prepare it or from jobbers. The purchaser or contractor or architect needs only to indicate that the structure will have about 4,000 sq ft (as an example) of exterior stone surface and that the course heights desired are deuces, fives, and eights. The stone will then come to the job strapped and on pallets in the proper proportions-proper, that is, for a good mason who is experienced in making pattern. An amateur, or even a good bricklayer who lacks much experience with stone, will use up the thicker courses in the early stages and finish the job with the shallow courses.

Some ingenious devices for finishing cut stone have been developed since World War II. Probably the greatest single change in capabilities has been the increasing availability of good hard-surface cutting material, such as tungsten carbide. Tools that formerly had to be returned to the shop for sharpening after a few hours, or even minutes, of use now cut effectively for many times as long.

The milling and stone-working capabilities

Figures 26-29 *(on facing page).* **26 (upper left when turned to viewing position), Capital being carved from a 7-ft cube for the rotunda added to the First Church of Christ Scientist in Boston; 27 (lower left), Planer dressing a stone surface to the required dimension; 28 (upper right), Carver shaping decorative work with a pneumatic chisel; and 29 (lower right), Hydraulic shearing machine (guillotine) snapping billets of standard height for splitface, job-fabricated ashlar masonry.**

of the district are more diverse than they have ever been before, but the total capacity is reduced. The number of firms engaged in the work has shrunk markedly, even since the early 1960's, and the sterile, slab-faced nature of much recent and current architecture has decreased the employment of specialized craftsmen. For the Bicentennial replication in three-dimensional stone of the painting showing Washington crossing the Delaware, carvers had to be called from retirement.

As counter to the losses occasioned by the diminution in decorative stonework, new developments in construction have required the industry to diversify its skills and to initiate techniques of its own. Composite panels using stone together with other materials, use of epoxy resins and other methods of bonding stone to stone and stone to backing, preassembled panels that are both exterior cladding and insulation, post-tensioned lintels, and one-piece floor-to-floor cladding as high as 28 ft have brought new procedures to an old field of endeavor

Byproducts and Use of Waste Materials

The dimension-stone industry has long been characterized by a high ratio of waste materials to salable prime product, both in quarrying and in fabrication. In the Indiana limestone district, the principal visual evidence has been the grout piles of overburden and unused building stone. It has seemed to the public that blocks and coarse waste fragments, once quarried, should have some use, and many ideas have been advanced (Mance, 1915a, 1915b) and attempts made to salvage the waste material for some purpose that would repay at least a part of its cost. The most common suggestion has been that it should be possible to crush the stone for one of the many purposes to which aggregates are put, but the waste is generally not well suited to most crushed-stone uses, and the cost of reworking the old grout piles is greater than the cost of obtaining new stone, freshly quarried by conventional crushed-stone quarry practices. The very size of the waste blocks induces handling and crushing expenses greater than the potential yield in dollars.

Some reclamation has taken place through the reworking of old grout piles for blocks usable as breakwater and in seawalls, but even for this purpose it has on occasion turned out to be more efficient to quarry afresh. Much of the material in grout piles has the lithology of building stone but was disqualified, at least at the time when it was quarried, by flaws of various sorts, and a typical specimen of the building stone does not have the resistance to abrasion required for Class A aggregate.

A smaller but appreciable amount of waste results from milling: roughbacks (the irregular edge slabs from the block that goes through the gang saws), trimmings from the circular saws, and chips, dust, and planings from various fabricating procedures. That most of the building stone is high-calcium limestone (more than 95 percent calcium carbonate content) suggests the easy answer of producing chemical limestone from the waste, and recovery for this purpose has been attempted, in some places successfully. Special plants at both Bedford and Bloomington formerly operated to collect and process mill wastes for one of the many purposes to which finely ground high-calcium limestone is essential and for agricultural limestone, but most of the waste remains waste. The fact is that the daily or weekly volume does not reach the level required for profitability, and, as is true in so many other situations in industry, the waste is waste because there is not enough of it. A potential customer who would be interested in 400 tons per week of material on a dependable basis is not interested in 20 tons per week average on an erratic schedule.

That no great success has yet been attained in reducing and using dimension-limestone waste should not deter the industry from continued efforts. Economics, including energy costs for producing nonrevenue materials, demand improvement in the situation, and both changing public attitudes and prospects of government regulation foretell a time, probably not distant, when better land reclamation will be mandatory.

Specifications and Tests

Because rocks are inhomogeneous and naturally formed materials, varying in such components as mineralogy, texture, cementa-

Table 1. Physical-constant data of Salem limestones[1]

Test[2]	Number of samples	Mean	Range[3]
Abrasion resistance C241 - 51	162	8.7	4.9 - 15.9
Absorption (weight percent) C97 - 47	154	5.4	2.8 - 8.6
Compressive strength (psi) C170 - 50	149	9,030[4]	5,050 - 14,800
Modulus of rupture (psi) C99 – 52	141	986[4]	427 - 1,760
Specific gravity C97 – 47	154	2.28	2.14 - 2.42

[1]From an open-file report of the Indiana Geological Survey, “Physical-Constant Data of the Salem Limestone,” by Myra H. Fox and Robert F. Blakely.

[2]Number below test description refers to designation by the American Society for Testing and Materials.

[3]These tests were run on a wide variety of Salem samples, including both finished stone of assumed building-stone quality and materials that were tested specifically because they were not expected to meet one or another of the desired specifications.

[4]Not true mean because data are not normally distributed.

tion, and moisture, and because test specimens cannot be prepared and tested uniformly, they exhibit variations in physical properties. Salem limestones show these variations (some not normal) in tests of resistance to abrasion, absorption, compressive strength, modulus of rupture, and specific gravity (table 1).

Both technical bodies and trade organizations have established standards to assure the quality of building stone, and testing procedures have been developed for determining whether materials meet stated requirements. Among the most widely recognized are those issued by the American Society for Testing and Materials (ASTM), which has issued Standard C119, Definition of Terms Relating to Natural Building Stones, a document that descriptively identifies granite, limestone, marble, greenstone, sandstone, slate, and varieties of some of them. ASTM specifications for various rock types include ANSI (American National Standards Institute)/ASTM Designation C568, Specification for Dimension Limestone, which classifies limestone on the basis of specific gravity into three categories designated I (Low-Density)limestone with density ranging from 110 through 135 lb/ft^3 (1.76 through 2.16 Mg/m^3), II (Medium-Density)--limestone with density greater than 135 and not greater than 160 lb /ft3 (2.16 through 2.56 Mg/m3), and III (High-Density)-limestone with density greater than 160 lb /ft^3 (2.56 Mg/m^3). The specification states that the dimension limestone supplied under the specification shall conform to the physical characteristics listed in a table that is reproduced here (table 2) with slight modifications.

The building limestone produced in the Bloomington-Bedford district falls into Category II (Medium-Density).

Table 2. Physical characteristics of building limestones

Categories	Absorption by weight, max, percent (Method C97)[1]	Compressive strength, min, psi[a] (MPa)[2] (Method C170)[3]	Modules of rupture, min, psi[a] (MPa)[2] (Method C99)1	Abrasion resistance, min, hardness[b] (Method C241)[5]
I	12	1800 (12)	400 (2.8)	*b*
II	7.5	4000 (28)	500 (3.4)	*b*
III	3	8000 (55)	1000 (6.9)	*b*

a - Obtained from dry specimens using average of values parallel and perpendicular to bedding planes.

b - Pertains only to stone subject to foot traffic. In stairways, floors, and platforms subject to heavy foot traffic, a minimum abrasion hardness of 10 is recommended.

[1] ANSI/ASTM C97 Standard Test Methods for Absorption and Bulk Specific Gravity of Natural Building Stone.

[2] MPa = Megapascal.

[3] ANSI/ASTM C170 Standard Test Method for Compressive Strength of Natural Building Stone.

[4] ANSI/ASTM C99 Standard Test Method for Modules of Rupture of Natural Building Stone.

[5] ANSI/ASTM C241 Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic.

Choice of Building Stone for Various Applications

Aesthetic considerations are more important than any others in the selection of building stone by architects for most purposes. Exceptions are surfaces subject to substantial wear from foot traffic; surfaces vulnerable to attrition and impact, such as base courses along sidewalks on exteriors; interior base courses likely to be affected by scrubbing, mopping, and chemicals; and exterior paving that may be damaged by salt or other deicing compounds.

Persons familiar with building stone are frequently asked what guidance the standards offer for selection of stone for specific construction projects, and the answer is that this is not their purpose, although they may be helpful. Examples of their usefulness are to be found in choice of stone for stair treads, flooring, and paving where the stipulation of minimum resistance to abrasion may be important, depending on the amount of traffic that may be expected. Absorption is a consideration where exposure to liquids, to spillage and soiling, or to freezing are likely to be factors. For the most part, however, the physical characteristics expressed in the standards are principally assurance to the consumer that the stone purchased falls within the satisfactory range for *the type of stone that has been selected.* Minimum compressive strength, for example, is not specified for the three categories of limestone to guarantee that the stone will not crush in use, as most construction practice does not subject the stone to vertical pressures that will pose a problem in this respect. Carrier (1960, p. 28) mentioned that the load on the stone at the base of the Washington Monument, a 555-ft-high load-bearing column, is only 600 lb/in^2. Hollow load-bearing concrete block used in the same way requires compressive strength of only 700 to 1,000 lb/in^2, and hollow block that is not load bearing (much building stone is not load bearing in use) has only 300 lb/in^2 minimum; one may ask, therefore, why the specified minimum compressive strength for Category II limestone is 4,000 lb/in^2. An analogy is to be found, in terms of human health, in the blood-pressure test, which is routinely taken as part of physical examinations and for diagnosis, but which does not in itself reveal the cause for high or low readings-only that some abnormality exists. Similarly, for stone, compressive strength that falls below the normal range for the type of stone being tested indicates possible flaws, or at least peculiarities, that suggest the possibility of performance unsatisfactory in ways *other than* compressive failure.

The ultimate test of whether stone is satisfactory for any given purpose is performance, and Indiana Limestone has withstood the test of time, for well over a century, in buildings of all sorts and in bridges and monuments distributed through a wide diversity of climates and environments. Such difficulties as have been encountered are largely attributable to placement in unsuitable situations (below grade, in constantly wet locations, or subject to salt action), to faulty construction procedures (improper anchorage or lack of expansion space), and to the effects of incompatible associated materials, for example, leaching of alkalis from mortar or concrete (McDonald, 1978?).

Outlook for the Building-Stone Field

The amount of stone in the outcrop belt of the Salem Limestone, and even in the present restricted producing district, is enormous. Quarrying to date has been exclusively by open-pit methods, although underground removal is entirely feasible and is a common practice elsewhere in the world, and the subsurface reserves dwarf the amount accessible by stripping. Land-use considerations are the principal limitation of future supplies. Development of land for residential use, shopping complexes, transportation, and a host of other uses constantly reduces the prospective territory for expansion of building-stone production. Zoning restrictions commonly accompany many land-development ventures, and it would be difficult even now to obtain approval for new quarry openings and even, in some places, expansion of existing quarries. Sheer increase in the value of land offers some deterrent; the mineral industries can rarely compete economically with any other land use except agriculture.

Several factors combine to offer encouragement for future use of stone. One is the increased interest in historic preservation during the past decade. Renovation or restoration of old buildings that have architectural or historic merit does not in itself provide any major market for stone. But additions to such structures frequently do, and the desire to maintain the architectural integrity of historic neighborhoods and districts prompts the use of style and material that resemble those of the older structures. Rapidly increasing costs of new construction favor the salvaging of sound old buildings and their adaptation to new uses.

Many types of building stone used in the 19th century, and even well into this century, are no longer available, but the Indiana industry has the capacity of duplicating and supplying masonry units that were ever available in Salem limestone (Patton, 1977, p. 68).

The life expectancy of many structures erected in the postwar years was assumed to be 30 years or less, and such ephemeral construction does not encourage the use of material as permanent stone, but many people in the construction field believe that the era of the throwaway building is passing, except for the throwaway uses, such as fast-food outlets and other endeavors that may themselves have scant likelihood of individual permanence.

Perhaps the greatest incentive for expanded use of stone will result from an energy situation that can only worsen for the foreseeable future. Production of building stone is not energy intensive. Compared with the energy requirement for building materials that must be processed by heat-cement, glass, brick, tile, plaster, some types of insulating material, and metals- the energy requirement for quarrying and fabricating building stone is low. To this advantage may be added the fact that increased mass of exterior walls eases the energy burden for heating and cooling. A consideration termed the “M” factor, developed by the Masonry Industry Committee, adjusts the static “U” factor (heat transmission coefficient) to the dynamics of buildings. It gives the thermal engineer another tool to use in calculating heat flow by crediting wall weight and degree days in the calculations. Greater mass in exterior walls may reduce both the amount of insulation required and the size of the air-conditioning and heating plant for a particular building (Indiana Limestone Institute, 1977, p. 8-9; Patton, 1978, p. 683, 687). To the extent that application of the "M" factor comes to influence design, prospects for masonry as a building medium should improve.

Finally, several decades of faddism in alternative building materials show some signs of having run their course. The architect who achieves a superb building must design something entirely different for the next client. This causes architects to cast around in the field of materials as well as in the field of design, and whenever a new building material comes on the market, if it is not just patently preposterous (and sometimes if it is), a considerable amount of it will be used for a time because it is new. It is a way of building a structure of different appearance. In the past three decades the construction industry has run through glass and plated metal panels, sheet aluminum, glazed and enameled and anodized metals, and various other materials, and this particular period of threshing about for special effects and experimentation with new products may be waning. Not all of the business, by any means, will return to the classic masonry materials-stone and brickbat stone is likely to receive its fair share.

Acknowledgment

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